Microwave and Infrared Radiometric Observations of Water Vapor and Clouds During the Pilot Observation Experiment

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During Phase Two of the Pilot Radiation OBservation Experiment (PROBE) held in Kavieng, Papua New Guinea, (January 6 - February 28, 1993) the NOAA Wave Propagation Laboratory operated a dual-frequency microwave water substance radiometer (MWSR) and a Fourier transform infrared radiometer (FTIR). A complete description of the goals of PROBE and of the suite of instruments deployed at the Kavieng site is given by Clements et al. in a separate article in this proceedings and in Clements et al. (1992). In this report, we summarize some of our experiences during PROBE, as well as present some preliminary data that were obtained during this experiment.

Logistics

The MWSR and FTIR were housed in a seatainer shipped from Boulder, Colorado, to Kavieng. Although minor difficulties were encountered in placing the seatainer at the PROBE site, all equipment and computers arrived intact. After a day of unpacking and set-up, the instruments were operating. Of course, we benefitted from the previous work done in setting up the PROBE site for power, telephones, and security. The only major problem that we encountered was in obtaining the liquid nitrogen (LN_2) that was necessary for calibrating the FTIR. Although we started working on the LN_2 problem at least six months before the start of the experiment, numerous unanticipated and frustrating delays in round trip shipping from Kavieng to Lae resulted in the arrival of LN_2 on January 22. In addition, a previous shipment of the 1500-liter container for Phase One of PROBE was vandalized en route with the end result that only a fraction of the amount reached the field site. However, due to special security precautions arranged by the LN_2 manufacturer, we were successful in obtaining two complete shipments during the Phase Two operation.

Dual-Frequency Microwave Water Substance Radiometer (MWSR)

The dual-frequency MWSR deployed was designed, constructed, and field-tested by WPL; a complete description of the previous system is given by Hogg et al. (1983). In addition to electronics upgrades, this instrument differed from earlier versions by operating the lower channel at 23.87 GHz rather than 20.6 GHz. Both generations of instruments were designed to run continuously, to provide unattended operations, and to operate in almost all weather conditions.

The characteristics of the new instrument are shown in Table 1. The internal gain calibration of the radiometers is done by switching between the antenna and two temperature-controlled blackbody loads; if weather permitted, external calibration was done approximately every day using the "tip cal" method (Hogg et al. 1983).

The observed radiance at the two frequencies is sensitive to column amounts of water vapor and cloud liquid. We

(a) On October 1, 1993, the Wave Propagation Laboratory (WPL) was renamed the Environmental Technology Laboratory. Because the work reported here was done before October 1, the text contains references to the WPL.

Table 1. Characteristics of the WPL dual-channel MWSR used in PROBE.

Operating frequencies	23.87 and 31.65 GHz
Viewing	Zenith
Antenna half-power beam width	5.0°
Bandwidth (double side band)	1 GHz
Integration time	30 sec
Sensitivity (for 30 sec)	0.1 K rms
Absolute accuracy	0.75 K

derive precipitable water vapor (PWV) and integrated cloud liquid (ICL) every 30 seconds (or in some cases, every two minutes) using a parameter retrieval technique known as "linear statistical inversion" (Westwater and Strand 1968). Our a priori data set was developed from Cross-chain Loran Atmospheric Sounding System (CLASS) radiosonde observations that were obtained during Phase One of PROBE. Previously, the statistical accuracies of the derived PWV were evaluated by comparison with National Weather Service (NWS) radiosonde data and with CLASS observations with resultant RMS differences of 1.7 and 1.1 mm RMS, respectively. The accuracy of derived ICL is estimated to be 10% to 20%. As discussed in the "Plans" section below, we believe that the MWSR can be combined with FTIR, a Wind Profiler/Radio Acoustic Sounding System (RASS), a cloud lidar, and a CLASS balloon facility to provide valuable data for a tropical site.

Fourier Transform Infrared Radiometer (FTIR)

The FTIR developed by WPL (Shaw et al. 1991) is a ground-based Fourier transform interferometer that is similar to the ground-based instrument being developed for the ARM Program (Revercomb et al. 1992). The FTIR is a compact and rugged Michelson interferometer, operating between roughly 500 and 2000 cm^{-1} (5.0-20.0 μm) with 1-cm^{-1} spectral resolution. Downwelling atmospheric emission in the entire bandwidth is viewed simultaneously with a single LN_2-cooled HgCdTe detector. A Fast Fourier Transform (FFT) of the measured interferogram then yields the emission power spectrum.

Our present design calls for viewing two blackbody calibration targets immediately following each complete atmospheric emission measurement. Collection of each spectrum takes about 1 second, and we average 100 such spectra to reduce random noise. With this technique, calibrated atmospheric spectra are collected about once every 6-10 minutes. We now have operated the instrument with the MWSR at the First ISCCP[a] Regional Experiment (FIRE) experiments in Coffeyville, Kansas, during November-December in 1991 and during PROBE.

Observations

The MWSR operated continuously through PROBE and, except for periods of rain, the data appear to be of high quality. Because of the problems in obtaining LN_2, the FTIR database is not as large, but about 20 days of high-quality calibrated spectra were taken. On two occasions during which all of the PROBE instruments were operating, down-looking radiometric observations from ER-2 aircraft were also taken over the Kavieng site. Examples of WPL radiometric data taken during PROBE are shown in Figures 1 and 2.

Figure 1 is a 24-hr time series of PWV and ICL data; Figure 2a is a FTIR spectrum during the known (from lidar observations) cirrus conditions; and Figure 2b is a FTIR spectrum during clear conditions.

(a) International Satellite Cloud Climatology Project.

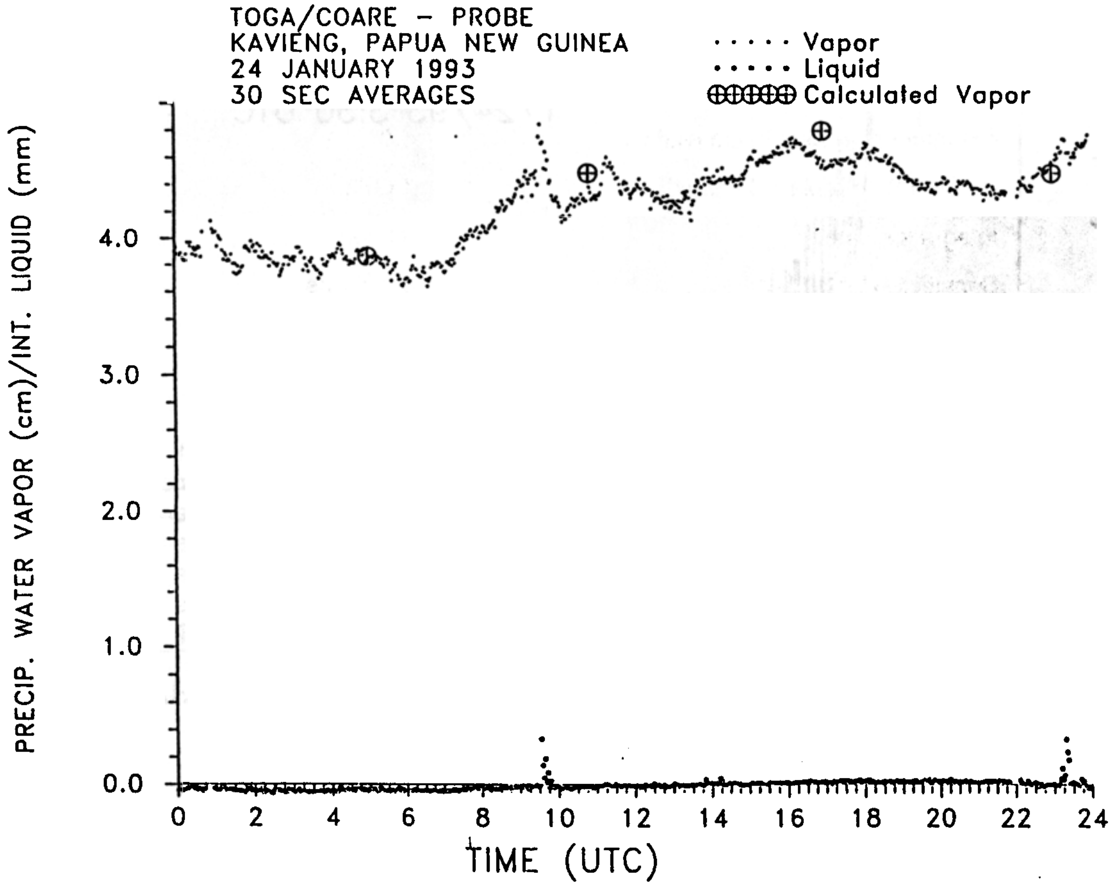

Figure 1. A 24-hr time series of precipitable water vapor and integrated cloud liquid derived from the MWSR, Kavieng, Papua New Guinea, 1/24/93. The crossed circles are PWV values derived from CLASS radiosondes.

Plans

Data that will be of immediate interest to WPL's radiometric analysis are CLASS observations of temperature and water vapor and lidar measurements of cloud height. We plan to investigate the following scientific questions:

1. Can tropical cirrus clouds be observed from the ground in narrow-band infrared spectra?
2. To what accuracy can clear-sky radiance be calculated from temperature, water vapor, and pressure profiles? Can we calculate radiance during cloudy conditions?
3. Are FTIRs and MWSRs useful for remote sensing of temperature, water vapor, and clouds in a tropical atmosphere? as complements to CLASS and RASS? for satellite validation and calibration?
4. How do short-term fluctuations of PWV and ICL compare with continental observations?

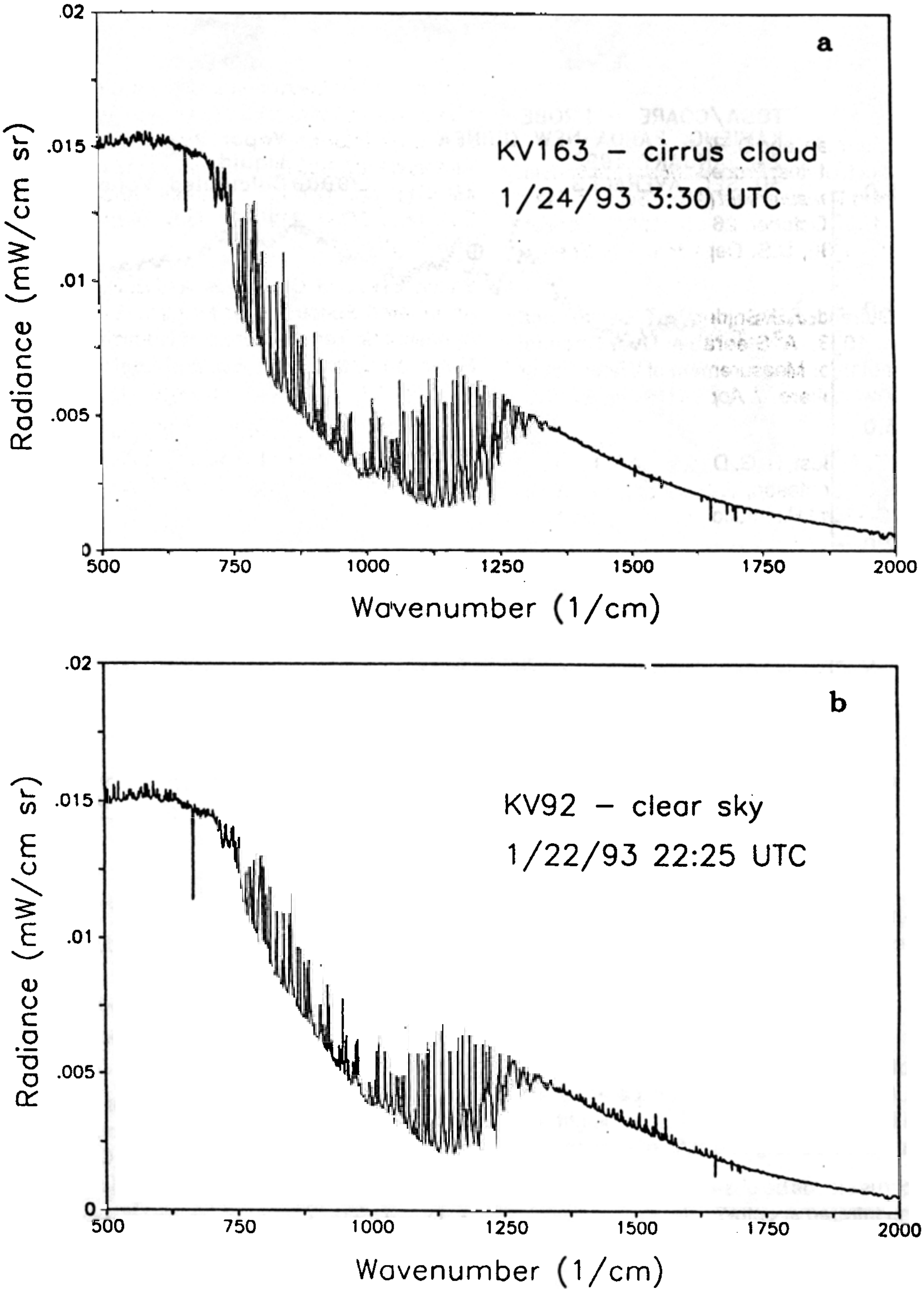

Figure 2. (a) FTIR spectrum of infrared radiance taken during the presence of cirrus clouds. Kavieng, Papua New Guinea, 0300 UTC, 1/24/93, (b) FTIR spectrum of infrared radiance taken during clear conditions, 1/22/93, 2225 UTC.

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